World Academy of Science, Engineering and Technology
International Journal of Materials and Textile Engineering
Vol:8, No:9, 2014

Textile Technology: Application in Sport and Medicine

R. Taiar

Open Science Index, Materials and Textile Engineering Vol:8, No:9, 2014 publications.waset.org/9999176.pdf

Abstract**—**Sport is one of the sectors in which the largest technical projections regarding the functions of textiles can be found. He is a large consumer of high performance composite materials and new fibers. It is one of the sectors where the innovation is the most important when the greatest numbers of spectacular developments are aimed at increasing performance. In medicine, textile innovation is used and contributes in the amelioration of different materials such as dressing, orthosis, bandages, etc. The hygienic textiles in non-woven materials record a strong growth. The objective of this study is to show the different advances of development we obtained in the both ways (sport and medicine). Polyamide fibers where developed tacking into account the specification of the high level athlete's performance like swimming and triathlon (Olympic Games, Brazil 2016). The first textile utilization was for skiing (Olympic Games, Sotchi 2014). The different textiles technologies where adapted for medicine.

Keywords**—**Medical textile, Smart textile, Sport textile, Textile innovation.

I. INTRODUCTION

THE textile innovation in high level sport is characterized by the performance, the functionality, comfort, the fashion and aesthetics.

The requirements of the sports activities direct industrials towards several optimizations, such as the reduction of friction, the thermoregulation improvement, the mechanical resistance, the safety, and the reduction in perspiration. In the medical environment, a technological development was observed during the ten last years. Based on their barrier effect, at their capacity of absorption, their biocompatibility and their contention capacity, the technical textiles manage to answer multiple features in this sector.

For example, the introduction of hydrophilic polymers made it possible to produce perfectly adhesive bandages. The arrival of certain elastanes and the improvement of a new method of knitting permitted the production of special compression stockings that are pleasant to carry. The development of biocompatible polymeric fibers made possible the use of the textiles in the osteosynthesis prostheses or in vascular surgery. The textile developments today concern not only the imitation of natural fibers, but also the development of new materials that adapt and react to the sensory and body conditions-the clothes we will use in the future will seem like second skin. After breathing fibers, the smart textile fibers adapt to the biological environment of the body. Reference [1] used the microcapsules in the t-shirt and the socks.

Several laboratories work on textiles using of the microcapsules containing of the substances with phase shift [2], [3]. The fabrics of Nylon and Lycra, coated with a conducting polymer (polypyrrole) conform to the shape of the human body [4], and function ideally as the biomechanical sensors which can be used in a range of applications to control the human movement. References [5], [6] studied the intrinsic electronic conducting polymers and the installation of the methods of manufacturing of conducting textile fibers. In medicine, 10% of the world technical textile volume are employed for health and can be improved with different technical future textile utilizations [7]. Currently, the smart textiles with integrated sensors are used in the medical field [8]. The new generation of biomedical sensors provides the opportunity for monitoring continually, ambulatory, as well as in residential environments. This generates complete information and allows for improvement of prevention, as well as treatment. Applications of the system "Sensate Liner" are intended for the medical supervision. This program develops and shows useful technologies to apply a systematic approach, making it possible to supervise the medical state of the patients, with a uniform equipped with sensors [8]. Current and future potential applications of three-dimensional polymeric reinforced fabrics manufactured by the processes: weaving, braiding, pricking and knitting, are studied [9]. The aim of our study is to show our last textiles development for the high level sport and medicine. The concerns of the present study include swimming and triathlon textiles for sports, and textile used for hemiplegic rehabilitation patients. Different engineering methods where used for the simulation, modelization and optimization fabrics.

II. MATERIALS AND METHODS

We developed 5 innovative fabric prototypes to answer to the exigencies of the high level athletes in swimming and triathlon in term of increasing performance and hemiplegic patients in terms of rehabilitation. We opted for the high-tech polyamide fibre, in the production of the textile Fig. 1.

R.T. is with the University of Reims Champagne Ardenne, Bp 1039 51687 Reims cedex 2, France (phone: 0032326918765; fax: 0032326918764; e-mail: redha.taiar@univ-reims.fr. www.redha.taiar.com).

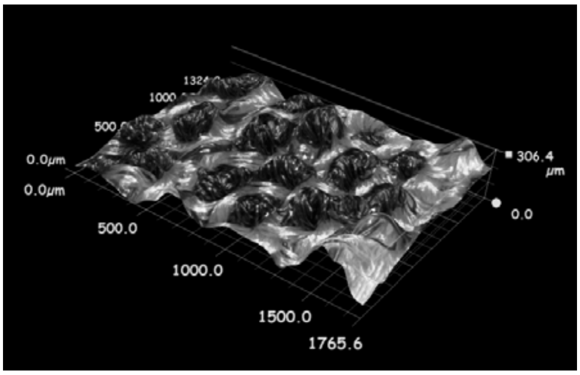


Fig. 1 Morphology of the textile developed and observed with high resolution microscope

The low density of the fibres makes it possible to produce a very lightweight fabric. The textile absorbs an extremely small amount of moisture, which means that the material cannot become saturated, hence slowing the swimmer down. When wet, polyamide fibres are almost as strong as when they are dry.

To quantify the morphology of the fabric surface, we used the Keyence microscope VHX Fig. 1 which offers an exceptional definition of observation (54 million pixels). The systems integrate a camera 3CCD high efficiency and permit the precise observation of details of 0.01 µm.

The textile developed is an extremely thin material and fits like a second skin Fig. 2.

Different tests were used in the aim to quantify the interaction between the water drop and the fabric. These tests allowed the study of the hydrophobicity of the fabric. If the fabric is hydrophobic the materials remain dry and don't get wet. Contrary, if the fabric is hydrophilic the material does get wet. To support this finding, 5 specific materials were examined in a laboratory and underwent a variety of tests.

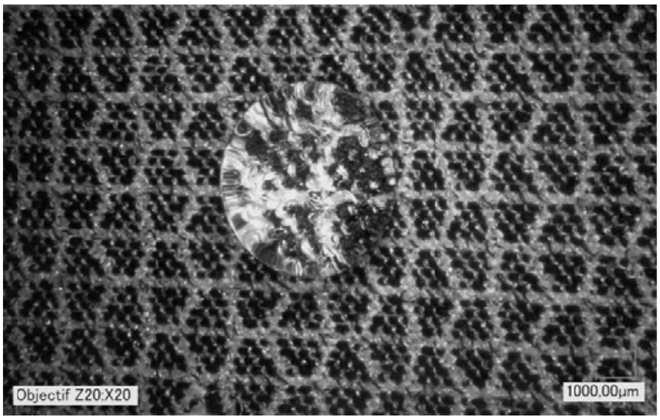


Fig. 2 Interaction between drop and the thin textile developed

In Static contact angles were measured with a GBX Digidrop apparatus fitted to a tilt able sample carrier supported by an x-y adjustable stage. This sample carrier was capable of a full of 360° rotation. Video cameras with a light source permit the view of the liquid drop. A finite drop volume of liquid was deposited on the horizontal substrate using a micro syringe. The contact angle is given as a function of time. Contact angle calculation was performed with the GBX scientific instrumentation software. This program allows a 50 image per second's analysis. An image of both sides of the drop was captured on a computer. Then the boundary of the drop was analyzed and contact angles were calculated. An equilibrium contact angle is determined when the drop reaches a metastable equilibrium. All equilibrium contact angles measurements were performed with 5µl drops. Each contact angle value θ_e found is associated to a thermodynamic metastable state for the three phase (solid/liquid/vapor) boundary. Generally, hysteresis is defined as the difference between the minimum of the values of contact angle measured, so called receding contact angle (θ_R), and the maximum of the values of contact angle measured, so-called advancing contact angle (θa).

For this experimentation ten measurements are often made and the numbers are averaged. A minimum drop volume is predicted for the critical inclined plane conditions. A 15µl liquid drop is retained for this experiment, and after drop deposition the plane was slowly tilted. The experimental configuration meant that the camera, light source, and substrate rotated in synchronization which made it easier to detect initial drop movement. Just before the drop began to move, the receding contact angle, the advancing contact angle, and the critical angle of tilt were recorded. Ten measurements were done for each result Fig. 3.

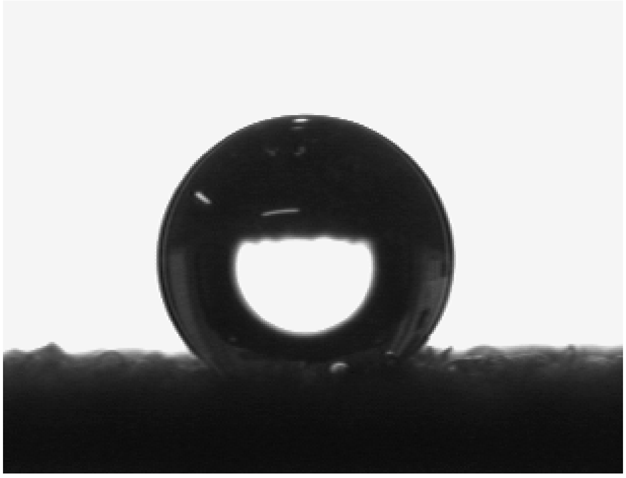
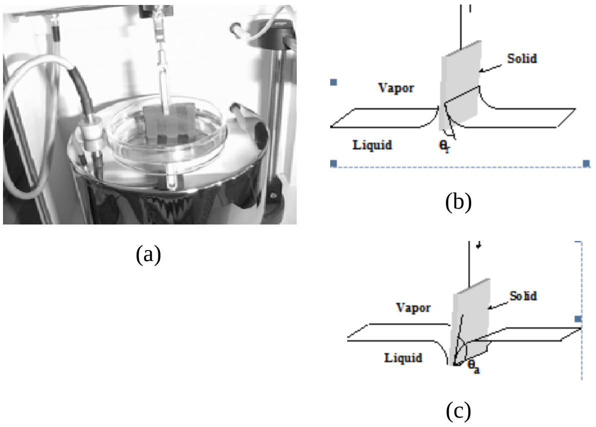


Fig. 3 Static drop interaction with fabrics

In the dynamic advancing and dynamic receding contact angles of water on the swimsuit sample were measured by the Wilhelmy plaque method Fig. 4 with K12 Krüss tensiometer. To begin the measurements, the sample suspended with the bottom edge nearly touching the surface of the liquid. This is the position of the zero force. The sample is lowered until it touches the liquid. This is the zero position. The force on the sample is measured as it is cycled slowly down and up. The depth of immersion of the sample is chosen to 15 mm and the rate of immersion and withdrawal cycles is fixed to 3 mm/min. The waiting time at the returned point is 10 seconds. For a textile sample given, when the immersion and withdrawal cycle is terminated the sample is replaced by another dry sample and the wetting cycle is repeated. Three cycles are repeated in that way. The analysis of these curves allows determines the angles of dynamic impact (angles of impact forward and backward impact). To quantify the difference in hysteresis between the fabrics we used the Wilcoxon-Mann-Whitney test ($p<0.05$).



(a)

(b)

(c)

Fig. 4 Illustration of the Wilhelmy plate method in (a), Withdrawal cycle in (b) and Immersion cycle in (c)

III. RESULTS AND DISCUSSION

The principal goal is to develop hydrophobic textiles able to prevent the absorption of the water droplet and facilitating the slip. When the contact angles (θ) remain superior to 90° the results indicate that the fabric is hydrophobic and lower than 90% the fabric is hydrophilic. Table I summarizes the different values of the static and dynamic angles obtained for the textiles tested (T1, T2, T3, T4 and T5).

TABLE I
CONTACT ANGLE OBTAINED IN STATIC AND DYNAMIC CONDITIONS

Fabrics	θ_E Static	θ_A Dynamic	θ_R Dynamic	$\theta_A - \theta_R$ Hysteresis
T1	142°	141°	107°	34°
T2	140°	136°	117°	19°
T3	141,5°	132°	109°	23°
T4	141	139°	90°	49°
T5	141,5°	132°	108°	24°

θ_E= static angle of contact in degree, θ_A= advancing angle of contact in degree, θ_R= receding contact angle in degree, Hysteresis= degree

In the static conditions the angles values are very close numerically to each other (between 140° and 142° in average). The high angle values indicated the hydrophobic characteristics of the different textiles tested. In static the drop maintained its morphology for a long time. The results for the textile behavior stay hydrophobic and remain dry. In dynamic mode, the values for the forward angles are equally close, between 132° and 141°. But, for the backwards contact angle the difference between fabrics is more significant (between 90° and 117°). In dynamic, during the fabric entry into the water the force necessary is more beneficial when the textile is hydrophobic. For the results, the drop doesn't glue to the fabric decreasing, friction and the boundary layer. We noted for the both measurements, static and dynamic, that the fabrics stay dry during the experimentations. The hysteresis corresponding to the difference between the forward angle and the backward angle indicated that the fabrics present the hydrophobic behavior. It was weakest for the fabric T2 and strongest for the fabric T4 and can be due also to the roughness, or to the heterogeneity of the surface. No significant difference was obtained in comparison of the hysteresis of the fabrics ($p>0.05$). In the present study we developed several prototypes which will be intended for the high level sport performance like swimming and the triathlon. These innovative processes will be adapted for medical use. The medical example relates the contribution of fabrics in helping hemiplegic patients float on the water's surface. This water rehabilitation will help decrease scabs on hemiplegics by reducing the contact between the body and the wheelchair.

IV. CONCLUSION

The solutions for medical and sports needs will increasingly take into account mechanical human specifications. In sports the performance improvement in the great events such as the Olympic Games is tributary in part by these textile technologies like swimming and triathlon. They will find their contribution in the amelioration of muscular work, the reduction of hydrodynamical and aerodynamical resistance. In medicine, the advanced textiles will permit the development of assistance solutions tools for patient function, such as passive or active resistance.

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Prof. Redha Taiar, Ph.D. Biomechanics, now is a Professor at the University of Reims Champaign France. Was Head of the Master of Biomechanics, Ergonomics and Clinical Research.

Head of the University diploma of Podiatric. He was also head of the laboratory of Biomechanics at the University of Reims, vice head of department of Sport Science. Head of RTBE (redha Taiar Biomechanical Engineering) Society developed for Sport and medical advice for industry. Vice-head of the congress of Physical Medicine and Rehabilitation Society (SOFMER, Reims, France 2013).

His researches focus on the industry engineering for medicine and high level sport. He is counsellor for different industries like “Arena” for the high level sport and “Sidas”, “Medicapteur” for the medical development.

For industry, his last work was for the “Notrax society” aimed to the conception and validation of anti-fatigue mats. For sport his last works focus on the development of swimsuit for triathlon and swimming for Brazil Olympic Games (2016) and the suit fabrics for skiing Olympic Games at Sotchi in 2014. He is a specialist in Biomechanics of health disease and rehabilitation.

Editorial Board of Series on Biomechanics Journal. Required as Reviewer for journal of Biomechanics, Journal of Human Movement Science, International Journal of Sports Medicine, the Sport Technology journal and journal of applied Biomechanics.

Different patents in his activities like “Development of the new kind of the knee rehabilitation tools for the high level athletes and pathological patients” and the “conception of the new shoe for the high level athletes and pathological subjects”.

All the information’s about Prof. Taiar can be found at the following address www.redha-taiar.com